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with this as the primary object will discover similar evidence of submerged shingle beaches at many other points around the island.

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UNIVERSITY OF CALIFORNIA,
Sept. 7, 1901.

ZONE OF MAXIMUM RICHNESS IN ORE BODIES.

FOR a long time, and among many mining people, the theory has prevailed that ore deposits have been derived from the interior of the earth, the mineral materials being carried upward to the surface by means of heated solutions. As a result, a maxim has been established that ore bodies necessarily get richer as depth increases. The fact that many exceptions have been found to this rule is ascribed to peculiar local conditions.

Aside from the bare statement of the general rule, no limitations have been formulated by the mining men. It has remained for the geologists to reach measurable results regarding the relative richness of ore bodies at varying depths. The results are not only very satisfactory, but they are totally at variance with the commonly assumed formulæ. Late investigations demonstrate, both theoretically and practically, that the problem has been wholly misunderstood by miners; and that the so-called empirical rule has very decided limitations.

Contrary to opinions heretofore generally held, many, if not most, ore bodies are believed not to be formed by the materials coming up in a superheated condition from great depths to the surface of the earth. Revolutionary as it may seem to many who have not followed carefully the trend of recent investigation, it appears to be a fact, nevertheless, that ore bodies are to be regarded as deposits formed very near the surface of the earth's crust; or, to be more precise, formed only in that thin outer part of the zone of the lithosphere which geologists are pleased to call the zone of fracture. Unusual richness which many ore deposits show at very shallow depths has come to be looked upon as due to local enrichment long after the first concentration has taken place.

Careful study of important ore bodies indi-

cates that after a certain depth is reached, there is frequently a very marked decrease in the amount of ore material, until finally in some cases the ores become too lean to work. From the point of view of origin, diminution in richness with depth is not, then, to be regarded as an actual depreciation in grade of the ore. The real status of the case is that the original deposition of the ore has in the upper zone undergone a greater or less augmentation in metallic content since the ore bodies first began to form.

As distinct processes, the rival theories of ascending solutions, descending solutions and laterally moving solutions no longer find countenance among those who have given the subject of ore genesis most attention, and especially among those who have approached the subject from the geological side. Ore deposition may take place through all three means, which may have equal importance. After an ore deposit has once formed under special geological conditions, the secondary enrichment which it may undergo is believed to take place largely under the influence of the descending solutions. Therefore, in the exploitation of ore bodies, everything goes to show how vitally important is a full consideration of the geological structures presented, both at the time of the first concentration and as subsequently assumed.

Under the title of 'Enrichment of Mineral Veins by Later Metallic Sulphides,' in the recently issued Volume XI. of the *Bulletin* of the Geological Society of America, Mr. W. H. Weed gives the results of his investigations concerning the zones of maximum richness in ore bodies. Briefly stated, the attempt is made to prove: (1) that the leaching of a relatively lean primary ore, commonly by surface waters, will supply the material in solution for such enrichment; (2) that the unaltered sulphides, especially pyrite, will induce precipitation, that the material precipitated is crystalline, and that a number of mineral species are commonly formed, and are now forming, in veins by such reactions; and (3) that such minerals deposited in quantity may form ore bodies of considerable size (bonanzas), or may be disseminated through the lean primary ore in strings and patches, thus enriching the ore body as a whole and

even making a former low-grade body of sufficient value to work.

It may be concluded that later enrichment of mineral veins is as important as the formation of the veins themselves, particularly from an economic standpoint. In many cases the enrichment proceeds along barren fractures and makes bonanzas. The enrichment is usually due to downward-moving surface waters, leaching the upper part of the vein and precipitating copper, silver, etc., by reaction with the unaltered ore below. As a consequence of this, veins do not increase in richness in depths below the zone of enrichment.

In the *Transactions* of the American Institute of Mining Engineers, Volume XXX., which is just being distributed, Mr. S. F. Emmons has a paper bearing upon this same subject of 'Secondary Enrichment of Ore Deposits.' The author draws upon his wide experience in calling attention to the many cases of secondary enrichment. The main theme discussed is summed up in the opening paragraphs, when he says that, 'admitting fully the general truth of the statement that the descending surface waters exert an oxidizing action, and hence that oxidation products within reach of the surface waters are the result of alteration by the latter, I have been led to believe, by observations now extending over a considerable number of years, that, under favorable conditions, the oxidation products may be changed back again into sulphides and redeposited as such, thus producing what may be called a sulphide enrichment of the original deposits. * * * Being rather a searcher after facts than a theorist, I am not deterred from accepting what may appear to me the correct reading of observed facts because it seems to contradict generally accepted theories.'

The same volume of the *Transactions* contains a practical application of Mr. Weed's theory to Montana deposits, under the title of the 'Enrichment of Gold and Silver Veins.' Attention is especially called to the dependence of such enrichments upon the presence of iron sulphide in the primary ore, and to the structural features which control the circulation of the enriching solutions below water-level. The process may be briefly described as follows. Leaching out of the metals from the portion of

the vein lying above ground-water level is to be considered as the main source of the enriching materials. The leaching is due to superficial alteration, and leaves the iron as a gossan, while the waters carrying the gold, silver, copper and other metals in solution trickle downward through the partially altered ores into cracks and water-courses which penetrate the ore body below the water-level. In weathering, the sulphides oxidize according to their relative affinity for oxygen and inversely as their affinity for sulphur. It is inferred from the evidence that ore bodies lacking in iron pyrite will not show enrichment, thus explaining the absence of any such phenomena in the pure silver-lead bodies of the Coeur d'Alene district and elsewhere.

CHARLES R. KEYES.

RECENT ZOO-PALEONTOLOGY.

VERTEBRATE PALEONTOLOGY AT THE CARNEGIE MUSEUM.

DURING the past summer three parties from the Department of Vertebrate Paleontology of the Carnegie Museum have been operating in our western fossil fields under the direction of Mr. J. B. Hatcher, the Museum's curator of vertebrate paleontology. One of these parties, in charge of Mr. O. A. Peterson, was sent to northwestern Nebraska to examine the Oligocene and Miocene deposits of that region. The work carried on by this party has been quite successful,—as might be expected from any party in charge of so experienced and skilled a collector of vertebrate fossils as is Mr. Peterson. Among other material secured may be mentioned as of especial value, skeletons of *Hoplophoneus*, *Daphænus*, *Oreodon*, *Procamelus* and *Merycochaerus*, all, it is believed, sufficiently perfect to admit of mounting as complete skeletons. A second party, in charge of Mr. C. W. Gilmore, was despatched to southern Wyoming to continue the work which has been carried on by the Museum for the past two years in the Jurassic deposits at Camp Carnegie, on Sheep Creek, in Albany Co., Wyoming. This party has met with the usual success attending the two previous expeditions